Mesoscopic spin-dependent transport in two-dimensional systems

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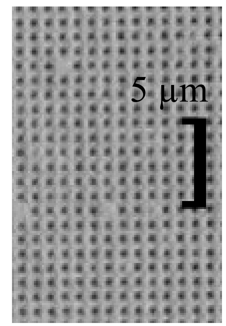
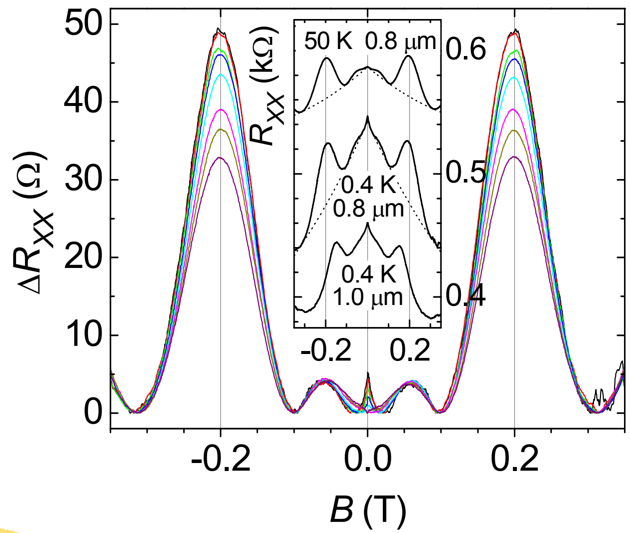
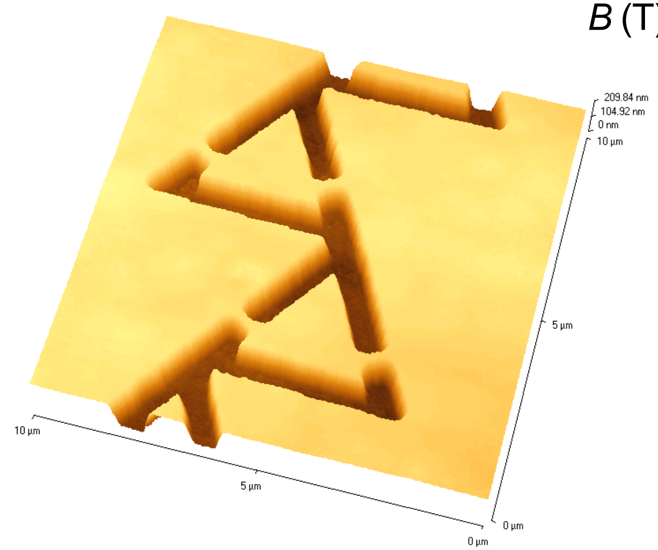
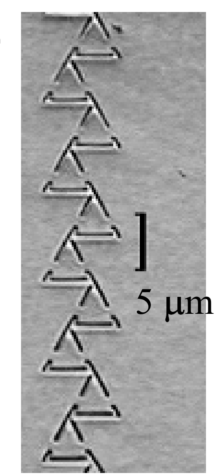
Present-day transistors are based on movement of charge. Future electronics may be based on a quantum property of the electron, spin: spintronics. Depending on the material, the influence of spin on the movement of electrons can be strong or weak. We study semiconductors such as InSb and InAs, where the interaction between spin and movement is strong. Those materials may offer possibilities for the control of spin in very small scale semiconductor devices. The top left picture shows InSb that has been patterned with small holes ("antidots"). We use this pattern to study the movement of electrons in InSb in a magnetic field. The top right figure shows how the sample resistance varies with the magnetic field. The bottom pictures show a very small scale electronic device we have fabricated on InSb to study how the spin influences the way an electron bounces off a wall. Such devices may also be useful to select one spin over another, important in spintronics. The walls are made by etching away the InSb, forming trenches, as indicated in the bottom left atomic force microscope picture.









A transistor that uses the electron spin instead of only the electron charge may be useful in a variety of computer applications, since it can lead to chips that consume less power, are smaller, and yet are more powerful for some tasks than presently existing chips. Semiconductors are used in transistors because semiconductors allow the fabrication of devices in which the electron charge can be moved with relative ease to convey information. But some semiconductors also exhibit strong spin-orbit interaction, by which the movement of the charge and the spin are linked. If we make semiconductor devices sufficiently small, that interaction between spin and movement can be used to create transistors that also utilize spin. Indeed, in small devices, the electrons move in a fashion that we have learned to predict in the last decade of nano-electronics work. Our work aims to use that previous work, and apply the knowledge of electron movement in small devices to the control of spin, through spin-orbit interaction. For instance, in the triangular devices pictured, electrons enter the triangles from one of the apertures in the side walls. Spin-orbit interaction leads to spin-dependent electron reflection from the triangles' bottom walls. Electrons with different spin reflect off the bottom wall in different directions. Depending on their spin, the electrons either exit through the opposing aperture, or do not exit. Hence, the triangles can serve to filter out electrons based on their spin.

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Outreach:
We have established a cooperative education program with a nearby two-year technical college (Hocking College). The technology involved in fabricating and measuring the spintronics devices presents an opportunity to the technical students to acquire skills the region presently does not offer. The students can utilize the skills and knowledge acquired in the cooperative education program to improve their participation in a high-technology area.

Education:
Undergraduate student Jonas Beardsley is building a variable temperature physical properties measurement system, using a closed-cycle pulse-tube cryogenic cooler. Undergraduate student Andrew McNamara is adapting our atomic force microscope to nanolithography, to reach even smaller dimensions for our spintronics devices. Graduate students John Peters and Yue Pan, as well as post-doc Hong Chen, contributed to this work.